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FOOD HABITS OF GEORGES BANK HADDOCK

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FOOD HABITS OF GEORGES BANK HADDOCK

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ABSTRACT

Stomach contents of 1,287 haddock, Melanogrammus aeglefinus, from Georges Bank were analyzed qualitatively and quantitatively. These specimens were caught by means of otter trawls during the period April 1953 to February 1954.

The haddock's diet consisted principally of sedentary or slow moving invertebrate animals; benthic and epi-benthic forms predominated. Small organisms were especially common in the food, presumably because the haddock's rather small mouth precludes taking large items. The percentage volume of each major food group in the diet was as follows: Crustacea - 33.1 percent; Mollusca - 17.5 percent; Echinodermata - 14.6 percent; Annelida - 9.9 percent; and Pisces - 1.9 percent.

Canadian biologists have reported that haddock on the offshore Nova Scotian banks fed predominately on fish. On Georges Bank crustaceans were found to be the primary food; fish constituted less than 2 percent of the food volume. Other notable differences were disclosed in the dietary composition of specimens collected from various parts of Georges Bank itself.

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FOOD HABITS OF GEORGES BANK HADDOCK

The Georges Bank haddock (Melanogrammus aeglefinus Linnaeus) fishery yields approximately 94 million pounds of fish annually. Production of this weight of fish requires many more times as much weight in food organisms. The fact that the total production of haddock does not vary widely from year to year indicates a fairly reliable and constant supply of food. Is this food supply reliable? Is it always composed of the same species of organisms? Does it vary from season to season? Does it differ from one part of the bank to another? Is it consistent from one year to another or are there violent changes which affect the abundance of new year classes as they begin their demersal existence? Are the movements of the haddock over the bank influenced by variations in the available food supply? Are the haddock selective in their food habits or do they take anything they can catch?

Georges Bank haddock are the fastest growing in the world. Is this the result of more abundant or more nutritious food? Some year classes grow faster than others. Is this related to variations in available food? What species of fish compete with haddock for the same foods and how detrimental is this competition?

These are some of the questions which the food habits project of the North Atlantic Fishery Investigations is attempting to answer. The initial work in this study is the examination and analysis of stomach contents collected primarily on commercial trawlers. No experimental design could be followed during this stage of the study when observers were collecting stomachs wherever the fishermen happened to fish.

The second stage of this study calls for (1) sampling according to plan using the Albatross III to fill in where samples from commercial trawlers are lacking; and (2) sampling the bottom invertebrate fauna in the areas where stomach samples are taken in order to relate the food captured by haddock with the presence of food organisms.

This report presents the results of the first year's study of haddock food habits.

European biologists have long been interested in the food habits of haddock and they have carried out many investigations on this subject. Food studies of haddock taken from waters surrounding the British Isles have been particularly numerous. MacIntosh (1874), Trechman (1888), Smith (1892), Scott, A. (1896), Scott, T. (1902), Todd (1905, 1907), Carr (1907, 1909), Bowman (1923), Ritchie (1937), and Jones (1954) are the most important contributors. They found echinoderms, mollusks, crustaceans, annelids, and fish to be the common foods of haddock in that area. Ritchie (loc. cit.) made quantitative analyses of the stomach contents from thousands of haddock. His work is the most thorough study of haddock food habits that has been made. Haddock from Scandinavian waters, as reported by Idelson (1929), Blegvad (1917), and Poulsen (1928), were found to subsist largely upon mollusks, echinoderms, annelids, and crustaceans. Food of haddock from Icelandic waters has been reported by Thompson (1929), Brown and Cheng (1946), and Fridriksson and Timmermann (1950). Echinoderms and annelids were the predominant food items; crustaceans, mollusks, and fish occurred less frequently.

North American biologists have carried out comparatively few investigations pertaining to haddock food habits. Haddock from Nova Scotian waters have been examined by Willis (1890), Needler (1929), Vladykov (1933), and Homans and Needler

(1944). The principal foods were fish, echinoderms, mollusks, and annelids. The work by Homans and Needler (loc. cit.) is the most complete food habit study of haddock from North American waters. Specimens from the coastal waters of Maine were found by Atwood (1865) and Kendall (1898) to feed chiefly on brittle-stars, sea urchins, and mollusks. From haddock taken in coastal waters of southern New England, Verrill (1871, 1873 = Baird 1889) reported mollusks, echinoderms, crustaceans, and annelids.

Bigelow and Schroeder (1953), in reference to haddock inhabiting the Gulf of Maine (Georges Bank included), state that large crustaceans, a great variety of gastropods and bivalve mollusks, worms, starfish, sea urchins, sand dollars, brittle-stars, and sea cucumbers all enter regularly into the haddock's dietary. Homans and Needler (1944) examined 179 small (10 - 30 centimeters) haddock from Georges Bank. The stomach contents consisted entirely of the shell-less gastropod Aeolis papillosa. Stomach contents of 1,500 haddock, also taken from Georges Bank, were examined by Clapp (1912). Sixty-eight species of mollusks are the only items listed. Clapp also observed that in certain parts of the northwest portion of Georges Bank the haddock feed heavily upon annelid worms.

It is apparent from the foregoing literature review that a comprehensive study of the food habits of haddock from Georges Bank - one of the greatest haddock producing areas in the world - has never been undertaken. It is the purpose of the present report to record the kinds of organisms Georges Bank haddock prey upon and, more specifically, to evaluate the relative importance of various groups of organisms in the dietary.

METHODS

This study was geographically restricted to that portion of the continental shelf east of Cape Cod, Massachusetts, known as Georges Bank. Most of the samples were taken from the northern and eastern parts of the bank, which are the areas most heavily fished by the commercial haddock-fishing fleet. The location at which each collection was made is plotted on the chart shown in figure 1. Specific information concerning each collection is listed in table 1. All specimens were collected with standard otter trawl gear operated from commercial fishing trawlers and the research vessel Albatross III.

This report is based upon the content analysis of 1,287 haddock stomachs from 38 collections taken during the 11-month period April 1953 to February 1954. An attempt was made to collect stomachs regularly throughout the year. However, samples are lacking for August and November because commercial fishing within the study area was too light to afford an opportunity to obtain samples.

Haddock utilized in this study ranged in size from 14 to 75 centimeters in length. The length-frequency distribution of these fish is listed in table 2. Most of the specimens were between 30 and 75 centimeters, which is the same size range of haddock captured by commercial trawlers. Inasmuch as the smaller specimens, those between 14 and 30 centimeters, were not commonly caught by standard gear, few specimens within that size range are represented.

Because detailed analysis of the stomach contents was required, the stomachs were collected at sea and brought to the laboratory for examination. Aboard ship, stomachs were removed from haddock and placed in a plastic bag containing 10 percent formalin. All stomachs from one collection were placed in the same container. A label bearing the date, location, water depth, time of capture, and cruise number was attached to the container. Since the procedure for collecting stomachs from haddock on commercial vessels

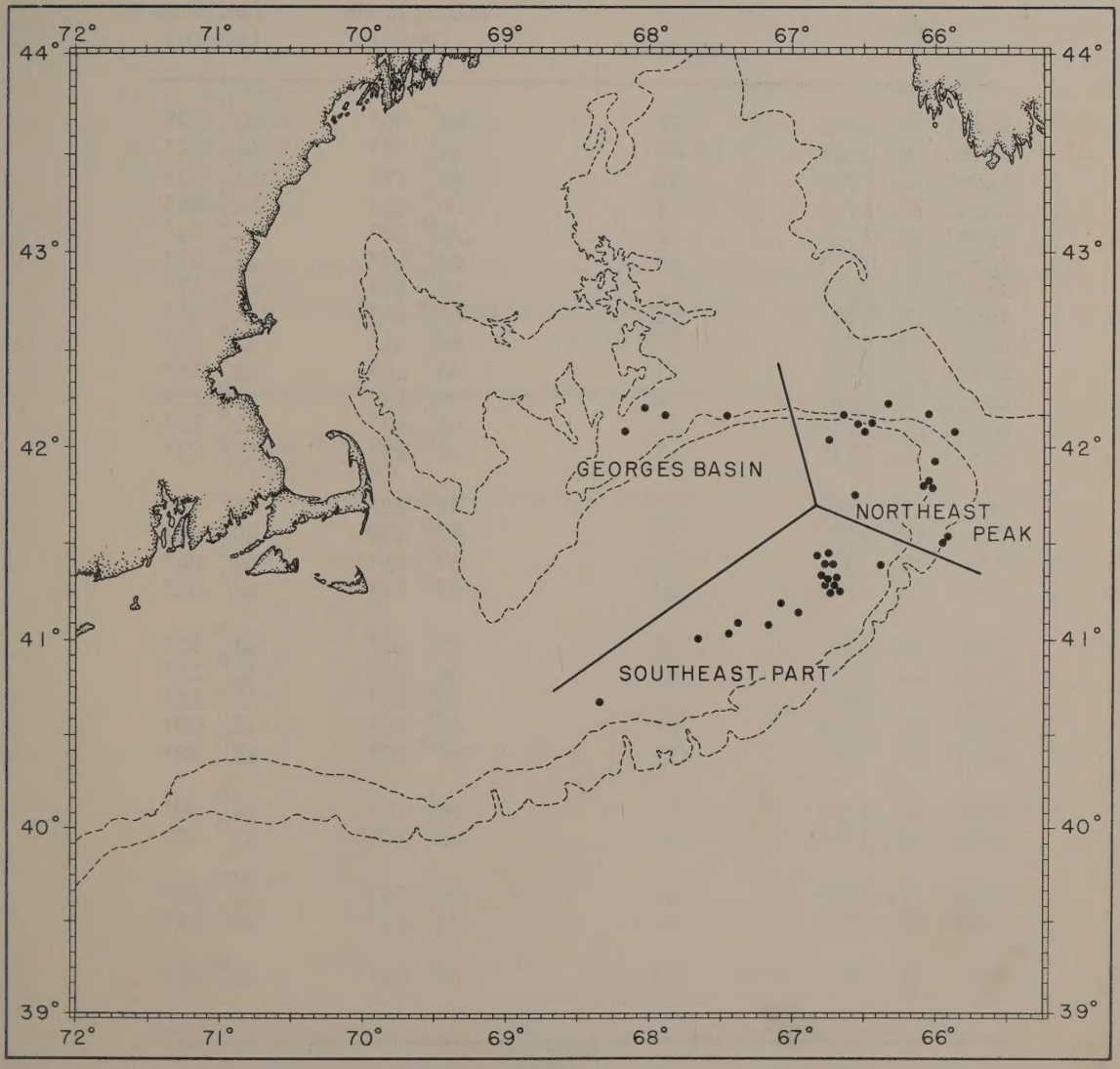

Figure 1.--Collection stations and food-type areas on Georges Bank.

Table 1.--List of haddock stomach collections

Date	Number of stomachs	Longitude (west)	Latitude (north)
April 2, 1953	21	66° 05'	41° 50'
April 4, 1953	29	65° 57'	41° 32'
April 4, 1953	33	65° 57'	41° 32'
April 10, 1953	7	66° 44'	41° 24'
April 10, 1953	11	66° 48'	41° 24'
April 11, 1953	16	66° 48'	41° 20'
April 11, 1953	15	66° 48'	41° 17'
April 12, 1953	18	66° 44'	41° 26'
April 12, 1953	30	66° 44	41° 26'
April 12, 1953	37	66° 44'	41° 15'
April 12, 1953	4	66° 43'	41° 16'
April 12, 1953	22	66° 43'	41° 18'
April 16, 1953	13	66° 25'	41° 23'
May 15, 1953	44	68° 22'	40° 40'
May 16, 1953	39	67° 40'	40° 59'
May 18, 1953	34	67° 25'	41° 04'
May 20, 1953	50	67° 12'	41° 04'
June 12, 1953	31	66° 46'	41° 15'
June 12, 1953	45	66° 46'	41° 15'
June 15, 1953	13	67° 05'	41° 11'
June 17, 1953	88	66° 58'	41° 09'
June 17, 1953	15	67° 27'	41° 02'
July 18, 1953	62	66° 04'	41° 50'
July 19, 1953	101	66° 30'	42° 07'
Sept. 19, 1953	47	66° 05'	42° 10'
Sept. 20, 1953	43	65° 55'	42° 05'
Oct. 11, 1953	53	66° 02'	41° 55'

Table 1.--List of haddock stomach collections - Continued

Date	Number of stomachs	Longitude (west)	Latitude (north)
Dec. 18, 1953	16	67° 55'	42° 10'
Dec. 19, 1953	37	67° 30'	42° 10'
Dec. 21, 1953	35	68° 03'	42° 12'
Jan. 20, 1954	28	68° 10'	42° 05'
Jan. 25, 1954	16	66° 16'	42° 13'
Feb. 3, 1954	28	66° 45'	42° 00'
Feb. 4, 1954	36	66° 30'	42° 05'
Feb. 17, 1954	26	66° 30'	42° 07'
Feb. 25, 1954	47	66° 05'	41° 50'
Feb. 28, 1954	62	66° 35'	41° 45'
Feb. 28, 1954	35	66° 40'	42° 10'

Table 2.--Length-frequency distribution of haddock examined 1/

Length class (centimeters)	Number
10.0 - 14.9	4
15.0 - 19.9	29
20.0 - 24.9	39
25.0 - 29.9	77
30.0 - 34.9	72
35.0 - 39.9	134
40.0 - 44.9	214
45.0 - 49.9	339
50.0 - 54.9	184
55.0 - 59.9	118
60.0 - 64.9	44
65.0 - 69.9	11
70.0 - 74.9	11
75.0 - 79.9	11
Total	1,287

1/ Direct measurement was made on 325 haddock; the lengths of 962 were estimated from stomach weights

(see page 6).

did not include measuring the body length of each fish, an alternative method had to be employed. Several methods for estimating body length from the size of stomach were tested. Body length estimates based upon linear measurements of the stomach proper were rejected because rather large errors resulted from their use. Gravimetric measurements were found to be fairly accurate, because even though the stomach dimensions varied according to the quantity of food within it, the weight of the empty stomach remained constant. The relationship between body length and stomach weight was determined from measurements on 325 haddock (table 3). A regression of this relationship is plotted in figure 2 and the standard deviation from regression (or standard error of the estimate) is indicated by the dashed lines. The regression formula is $\log Y = -0.0498 / 0.3557 \log X$ and the correlation coefficient is 0.972. It was possible to estimate the body length of a haddock by simply weighing the empty stomach and referring to the graph. Since only approximate body lengths were required for this work, the method worked out very satisfactorily.

In the laboratory the stomachs were opened and all contents removed for examination. The food mass in each stomach was measured volumetrically by water displacement. Food items were sorted to the lowest category to which they could be identified. They were then counted and the volume of each item was estimated. The volume of large items was measured in order to obviate large errors due to estimation. When numerous amphipods and small annelids were encountered, estimated totals were arrived at from counting a small sample.

RESULTS

Georges Bank haddock were found to be exceedingly omnivorous in habit. Three species of fish and nearly all major groups of marine invertebrate animals were represented in their diet. A large majority of the organisms in the haddock's dietary were sedentary or slow-moving benthic animals. Crustaceans were the primary food. Mollusks, echinoderms, and annelids comprised a substantial, but secondary, share of the diet. Fish were a minor component in the haddock's diet. The major categories of the stomach-content components for all specimens examined in this study are listed in table 4 and illustrated in figure 3.

Items of subordinate status in the haddock's dietary were grouped together under the heading Miscellaneous. These items consisted of 5 food categories and 2 non-food categories. The food categories were: Brachiopoda, Coelenterata, Nemertea, Turbellaria, Urochorda, and unidentified animal flesh. Non-food categories were: parasitic nematodes and sand and stone. Individually these miscellaneous groups were not especially abundant in the diet, but together they constituted a significant share.

Mucus was designated a major classification heading because of the large quantities (9.4 percent) encountered in the stomach contents. It was usually yellow in color and its consistency varied from cream- to jelly-like. Inasmuch as fish are known to possess mucus-producing glands in the mouth and pharynx, to provide a food lubricant, it seems likely that most of the mucus recovered from haddock stomachs originated in their mouth and pharyngeal region and was swallowed with their food.

The unidentified material encountered in the stomach contents was composed of approximately equal parts of relatively undigested fragments of invertebrate organisms and rather well macerated matter of undetermined origin.

One outstanding feature of the food

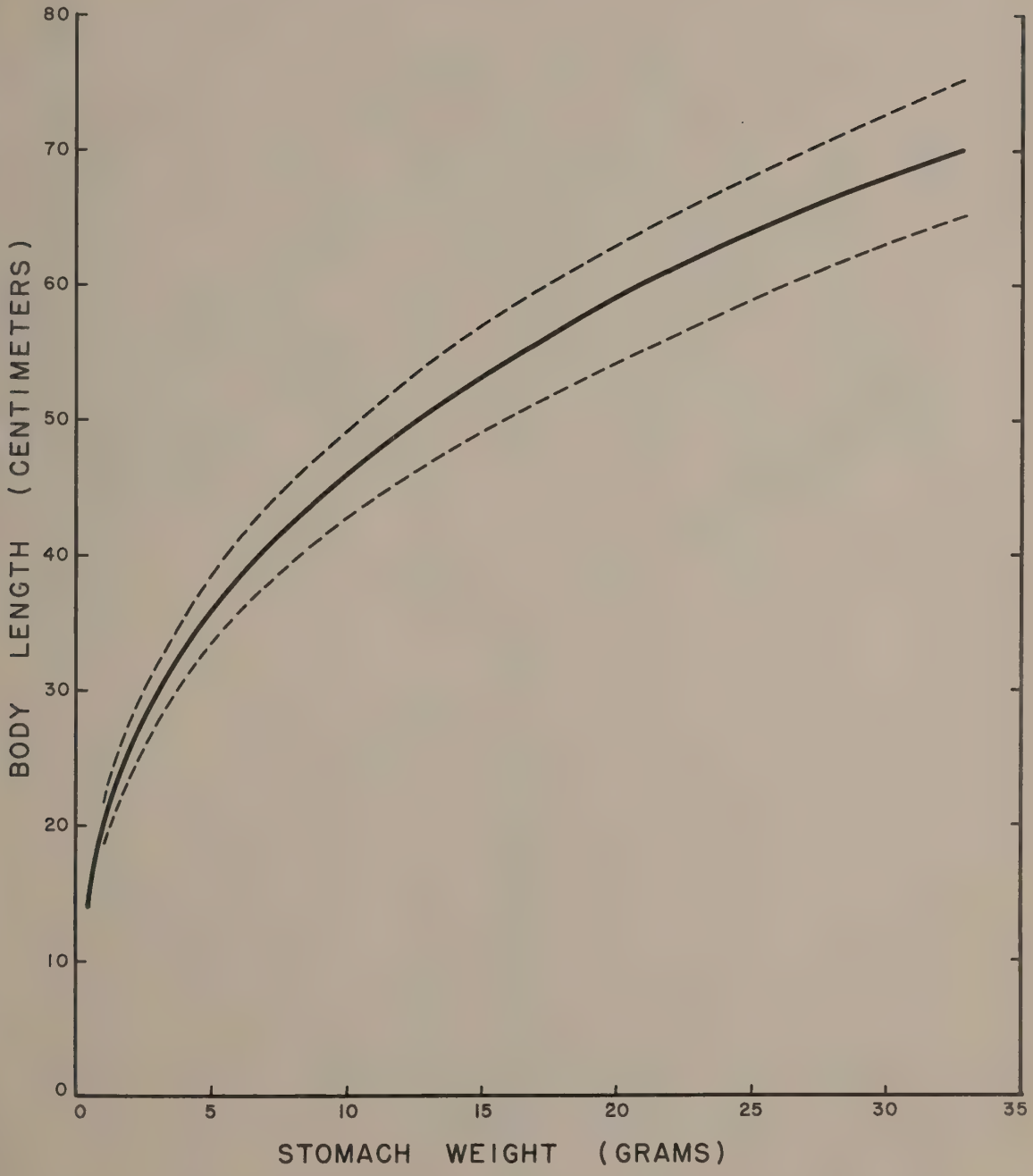

Figure 2.--Regression of body length on stomach weight. (Standard deviation from regression, which includes approximately two-thirds of the observations, are indicated by the dashed lines.)

Table 3.--Body (fork) length and empty stomach weight of 325 haddock

Body length (centimeters)	Stomach weight (grams)	Body length (centimeters)	Stomach weight (grams)	Body length (centimeters)	Stomach weight (grams)	Body length (centimeters)	Stomach weight (grams)	Body length (centimeters)	Stomach weight (grams)	Body length (centimeters)	Stomach weight (grams)
14	0.5	27	1.7	36	6.5	39	7.5	42	10.0	47	8.2
15	0.5	28	1.8	36	6.5	39	7.5	42	11.5	47	9.5
15	0.8	29	2.5	36	6.5	39	8.5	43	5.0	47	9.5
15	0.9	30	2.7	37	3.5	39	9.0	43	6.5	47	10.0
16	0.6	30	3.0	37	4.0	40	5.5	43	7.0	47	10.0
16	0.8	30	3.0	37	4.5	40	5.5	43	7.5	47	12.0
17	0.6	31	2.5	37	4.6	40	6.0	43	7.5	47	13.0
17	0.8	31	3.0	37	4.7	40	6.0	43	7.5	48	6.0
17	0.9	32	3.5	37	5.0	40	6.0	43	7.5	48	7.8
18	0.7	32	3.5	37	5.0	40	6.0	43	8.0	48	9.0
18	1.0	32	3.5	37	5.0	40	6.0	43	8.5	48	10.5
19	0.7	32	4.5	37	5.2	40	6.0	43	9.2	48	10.6
19	0.7	33	3.0	37	5.2	40	6.5	43	9.5	48	11.0
19	1.0	33	3.2	37	5.3	40	6.5	43	10.0	48	11.5
19	1.0	33	4.8	37	5.5	40	6.5	43	10.5	48	11.5
19	1.2	34	3.8	37	5.5	40	6.5	44	6.0	48	12.0
20	0.6	34	4.0	37	6.0	40	7.0	44	6.5	48	12.0
20	1.0	34	4.0	37	6.0	40	7.5	44	7.0	48	14.5
20	1.0	34	4.0	37	6.0	40	8.0	44	7.0	49	11.0
20	1.0	34	4.5	37	6.5	40	8.0	44	7.5	49	12.0
21	0.8	34	4.7	37	6.5	40	8.0	44	7.5	49	13.0
21	1.0	34	4.7	37	6.5	40	10.0	44	7.8	49	13.0
21	1.1	34	5.0	37	6.5	41	5.5	44	8.0	49	14.0
22	0.9	34	5.0	37	7.0	41	5.7	44	8.5	50	10.0
22	1.4	34	5.3	37	7.5	41	6.0	44	8.5	50	12.0
22	1.7	35	3.4	38	4.5	41	6.4	44	8.7	50	12.5
23	2.0	35	3.5	38	5.5	41	6.5	44	9.0	50	15.5
23	2.5	35	3.5	38	5.5	41	6.5	44	10.0	50	17.5
24	1.1	35	3.5	38	5.5	41	6.5	44	10.0	51	11.0
24	1.2	35	3.7	38	5.5	41	6.5	44	10.0	51	12.5
24	1.5	35	4.0	38	5.5	41	6.6	44	11.0	51	15.0
24	1.7	35	4.0	38	5.5	41	7.2	45	6.5	51	16.0
24	2.5	35	4.5	38	5.6	41	7.5	45	6.8	51	17.0
24	2.5	35	4.5	38	6.0	41	8.5	45	6.8	52	12.5
24	3.0	35	5.0	38	6.0	41	10.0	45	7.0	52	13.0
25	1.5	35	5.0	38	6.0	41	10.0	45	7.5	52	15.0
25	1.5	35	6.0	38	6.0	41	11.5	45	7.5	52	15.5
25	1.7	35	6.0	38	6.0	42	5.5	45	7.7	52	16.0
25	2.0	35	6.5	38	6.0	42	6.2	45	8.5	53	14.5
25	2.2	36	3.5	38	6.5	42	6.5	45	8.7	53	21.0
25	2.3	36	3.5	38	6.5	42	6.5	45	9.5	54	14.0
25	2.5	36	3.7	38	7.0	42	6.5	45	10.0	54	15.0
25	2.5	36	4.5	38	7.1	42	6.5	45	11.0	56	19.0
25	2.5	36	4.5	38	9.0	42	7.0	46	7.0	56	21.0
25	2.5	36	4.5	39	3.7	42	7.3	46	7.7	56	22.0
25	2.5	36	4.5	39	4.5	42	7.7	46	8.5	57	24.0
25	2.5	36	4.7	39	4.5	42	7.7	46	9.1	60	19.5
25	2.8	36	5.0	39	5.6	42	8.0	46	9.5	60	21.0
25	3.0	36	5.0	39	6.0	42	8.0	46	9.5	60	24.0
25	3.0	36	5.0	39	6.4	42	8.5	46	10.0	62	19.0
26	1.6	36	5.2	39	7.0	42	8.5	46	11.0	62	22.0
26	1.9	36	5.5	39	7.0	42	8.5	46	11.0	62	26.5
26	2.0	36	6.0	39	7.0	42	9.5	46	12.0	66	30.0
26	2.4	36	6.0	39	7.0	42	10.0	46	12.0	68	26.0
										74	32.0

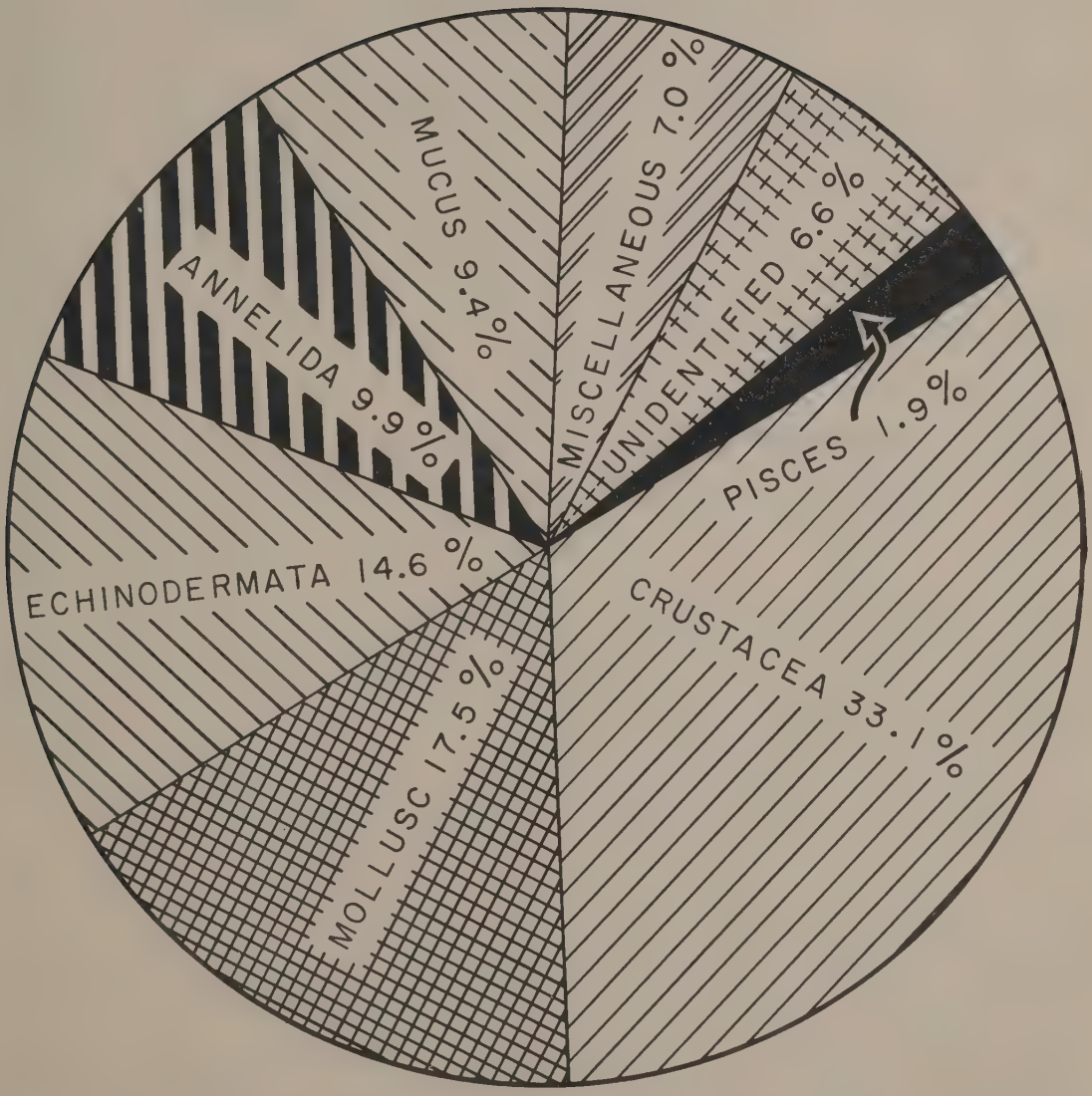

Figure 3.--Composition of haddock stomach contents expressed as percentage volume.

Table 4.--Stomach content composition of Georges Bank haddock

Category	Total volume	
	Cubic centimeters	Percentage
Crustacea	952.5	33.1
Mollusca	505.1	17.5
Echinodermata	421.1	14.6
Annelida	286.0	9.9
Pisces	54.9	1.9
Miscellaneous	202.2	7.0
Mucus	271.5	9.4
Unidentified	190.2	6.6

habits of Georges Bank haddock revealed by this study was the noticeably small quantities of fish in the diet. In view of the finding of Homans and Needler (1944) that haddock on the Nova Scotian banks feed heavily upon fish, it was more or less expected that Georges Bank haddock would have a somewhat similar diet. The food of haddock from the Nova Scotian banks was reported to consist of 53.0 percent (by weight) fish, nearly all of which was made up by one species, the sand launce, Ammodytes americanus DeKay. In contrast to this, fish made up only 1.9 percent (by volume) of the diet of Georges Bank haddock, and the sand launce constituted only a small part of this amount. The explanation for such diverse food habits of haddock on these adjacent offshore banks will not be forthcoming until more information is obtained on the benthic fauna.

FOOD-TYPE AREAS

Haddock collection stations were clustered in three more or less separate geographical areas of Georges Bank (figure 1). From stomach analyses made so far, the foods eaten by haddock in each area were sufficiently distinctive and consistent enough to warrant the establishment of three food-type areas. These areas and the organisms characteristic of each are as follows:

Georges Basin[1/]: Parathemisto (amphipod)
Cuspidaria (pelecypod)

Northeast Peak: Hyas (toad crab)
Eunice (annelid)

Southeast Part: Echinarachnius (sand dollar)
Byblis (amphipod)

These index organisms were representative of the specific area either (1) because of their occurrence in large quantities in haddock stomachs from one particular area, even though found in small quantities in other areas, or (2) because they have been encountered in haddock stomachs from only one area, even though present in small quantities. The location and delineation of each food-type area is diagrammed in figure 1. A modification of these areas will no doubt be necessary when the food habits of haddock inhabiting the central and western parts of the bank become known.

Georges Basin

Adjacent to the northwestern perimeter of Georges Bank the ocean bottom forms a channel-like depression known as Georges Basin. Its depth is approximately 125 fathoms and the substrate is composed mostly of gray mud and sand. Food habits of haddock from this area are known from the stomach analysis of 116 specimens from 4 collection stations. Mean body length of the specimens was 57 centimeters; minimum and maximum length were 45 and 75 centimeters, respectively. Their average stomach content volume was 3.33 cubic centimeters. Stomach contents of the Georges Basin samples are itemized in table 5.

Georges Basin haddock ingested enormous quantities of ophiuroids (brittle-stars). Annelid worms and urochordates were taken in moderately small quantities. Relatively minor amounts of crustaceans, mollusks, fish, and echinoderms other than the Ophiuroidea were eaten by haddock in this particular area.

The food items of outstanding importance to the Georges Basin haddock, both in number and volume, were the Ophiuroidea. They constituted 47.2 percent of the total volume and were present in 43 percent of the specimens. Species of brittle-stars most frequently encountered were: Ophiura robusta Ayers, Ophiura sarsi Lutken, and Ophiopholis aculeata (Linnaeus). Other groups of echinoderms, namely, the echinoids, asteroids,

1/-Names applied to areas of Georges Bank were taken from U.S. Coast and Geodetic Survey Chart number 71.

Table 5.--Stomach contents of 116 haddock from Georges Basin

Food groups	Number of organisms	Occurrence in stomach		Total volume	
		Number of stomachs	Percentage of stomachs 1/	Cubic centimeters	Percentage 2/
Crustacea	476	71	61	18.6	4.8
Amphipoda	439	64	55	9.3	2.4
Decapoda	5	5	4	1.7	0.4
Isopoda	5	3	3	0.3	0.1
Euphausiacea	27	13	11	7.3	1.9
Cirripedia	--	--	--	--	--
Mysidacea	--	--	--	--	--
Cumacea	--	--	--	--	--
Unidentified	--	--	--	--	--
Mollusca	292	42	36	15.6	4.0
Cephalopoda	--	--	--	--	--
Pelecypoda	219	34	29	8.0	2.0
Gastropoda	37	15	13	2.6	0.7
Amphineura	10	5	4	2.7	0.7
Scaphopoda	26	12	10	2.3	0.6
Unidentified	--	--	--	--	--
Echinodermata	5,038	55	47	200.4	52.0
Ophiuroidea	5,022	50	43	182.0	47.2
Echinoidea	10	7	6	13.4	3.5
Holothuroidea	1	1	1	3.0	0.8
Asteroidea	5	5	4	2.0	0.5
Unidentified	--	--	--	--	--
Annelida	186	42	36	39.5	10.2
Nereidiformia	54	12	10	8.1	2.1
Scoleciformia	9	3	3	2.7	0.7
Terebelliformia	2	1	1	0.3	0.1
Cryptocephala	5	1	1	4.5	1.2
Spioniformia	5	2	2	0.1	Trace
Sipunculida	20	4	3	4.0	1.0
Unidentified	91	33	28	19.8	5.1
Pisces	1	1	1	2.0	0.5
Miscellaneous	49	21	18	38.0	9.9
Urochorda	27	8	7	31.8	8.2
Coelenterata	2	2	2	0.6	0.2
Nemertea	--	--	--	--	--
Sand and stone	18	7	6	3.4	0.9
Animal flesh	2	2	2	0.7	0.2
Brachiopoda	4	3	3	1.5	0.4
Turbellaria	--	--	--	--	--
Nematoda	--	--	--	--	--
Mucus	--	70	60	44.2	11.5
Unidentified	--	34	29	27.4	7.1

1/ Values less than 1.0 per cent are listed as trace.
2/ Values less than 0.1 per cent are listed as trace.

and holothurians, made up less than 5 percent of the stomach contents.

Unusually small quantities of crustaceans were found in the diet of Georges Basin haddock. In samples from the Northeast Peak and Southeast Part, crustaceans constituted 30 to 40 percent of the food, in contrast to 5 percent found in the Georges Basin samples. Euphausiids were represented by a single species, Meganyctiphanes norvegica M. Sars. Although this species was found in haddock from the Northeast Peak, it was much more common in Georges Basin samples. Hyperiid amphipods were comparatively abundant in Georges Basin haddock, and one species, Parathemisto compressa (Göes), was one of the animals distinctive to this food-type area.

Pelagic tunicates, listed under the heading Urochorda in the miscellaneous group, were rather common food items in this area. They provided 8.2 percent of the food for Georges Basin haddock. The aggregate form of Salpa zonaria (Pallas) was the predominant species.

Even though haddock from this food-type area were large and thereby better adapted for engulfing fish, only an insignificant quantity of fish or fish remains, 0.5 percent by volume, was present in their diet.

Histograms illustrating the percentage volume of the stomach contents of haddock from each food-type area are presented in figure 4. Differences in stomach-content composition of Georges Basin haddock as compared with other areas are readily apparent.

Northeast Peak

The most easterly portion of Georges Bank, including nearly one-fifth the total bank area, is designated the Northeast Peak. Water depths in this area range from 30 to 100 fathoms, although most of it is between 40 and 50 fathoms. Sand with gravel and shell fragments are the predominant substrate components. Food habits of haddock from this food-type area were determined from the stomach analysis of 639 specimens from 15 collection stations. Mean body length of these haddock was 46 centimeters; extremes in length were 14 and 75 centimeters. Their average stomach content volume was 1.93 cubic centimeters.

Crustaceans were the primary food of haddock in this area, followed closely in importance by the mollusks and echinoderms. Annelids, fish, and the miscellaneous animal groups made up only a small portion of the diet. In table 6 the frequency, number, and volume of the food organisms are enumerated

Decapod crustaceans were an especially common food of haddock from the Northeast Peak. They alone accounted for 22.1 percent of the total stomach-content volume. The toad crab, Hyas coarctatus Leach, was the decapod taken in the greatest quantity. Because of the large amount of toad crabs eaten, and because their occurrence in the diet was restricted to the Northeast Peak, this species was selected as one of the index organisms characteristic of this food-type area. Cancer irroratus Say, Pandalus borealis Kroyer, Dichelopandalus leptocerus (Smith), and several species of Pagurus were other crustaceans prominent in the diet.

Among the mollusks that were preyed upon by haddock, the squid, Illex illecebrosus Lesueur, made up the greatest volume but were taken by relatively few haddock. Gastropods and pelecypods occurred in approximately equal amounts, with each providing slightly more than 5 percent of the food. Anachis haliaeeti Jeffreys, Cerastoderma pinnulatum Conrad, Astarte undata Gould, and Placopecten magellanicus Gmelin were some of the species frequently eaten. It was interesting to note that the only portions of the sea scallo

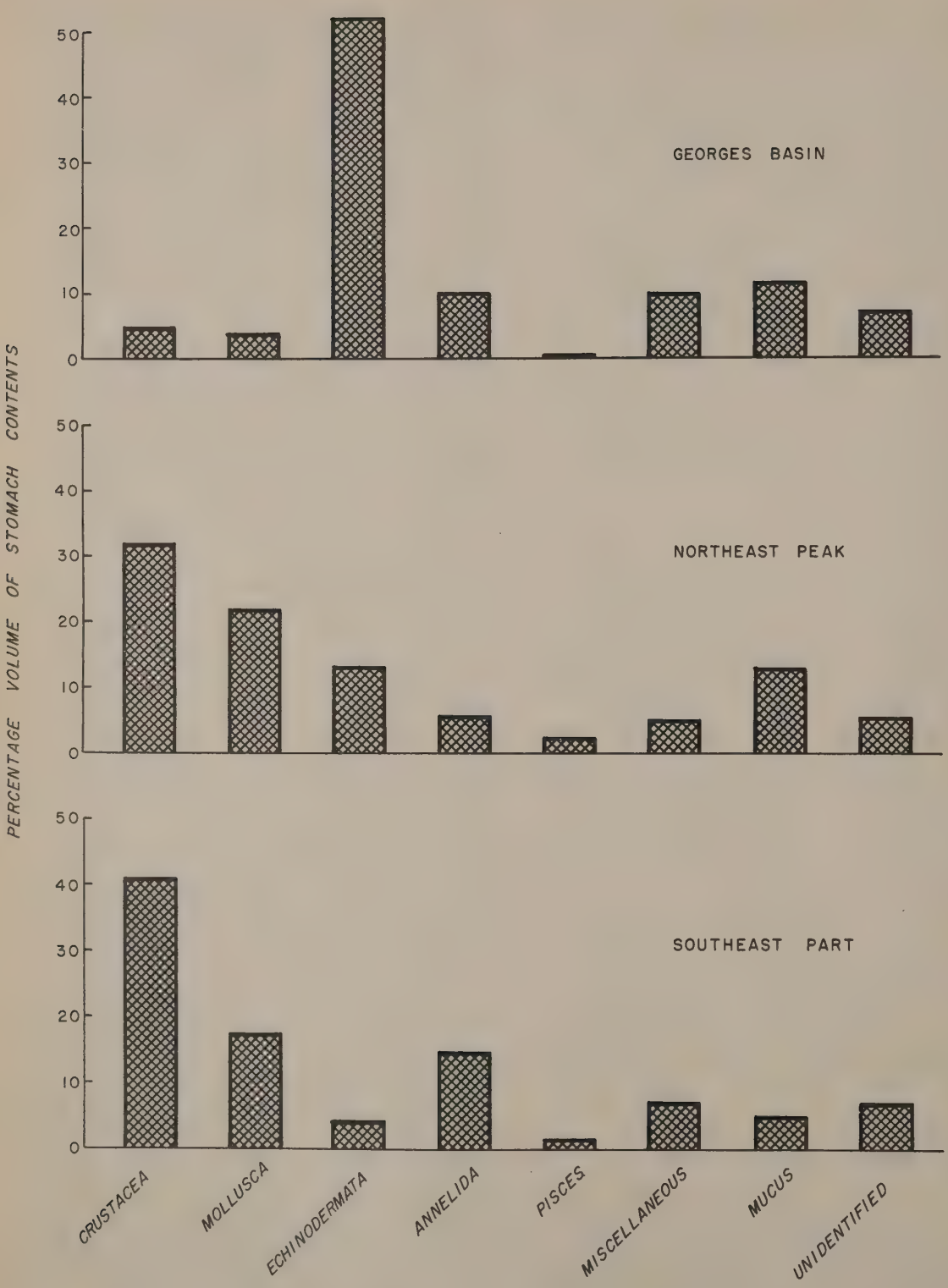

Figure 4.--Stomach contents of haddock from three food-type areas.

Table 6.--Stomach contents of 639 haddock from the Northeast Peak of Georges Bank

Food groups	Number of organisms	Occurrence in stomach		Total volume	
		Number of stomachs	Percentage of stomachs 1/	Cubic centimeters	Percentage 2/
Crustacea	4,901	385	60	407.0	32.3
Amphipoda	3,805	262	41	97.4	7.7
Decapoda	628	224	35	277.8	22.1
Isopoda	63	31	5	6.3	0.5
Euphausiacea	26	18	3	5.1	0.4
Cirripedia	7	3	Trace	10.4	0.8
Mysidacea	363	13	2	8.2	0.7
Cumacea	5	5	1	0.1	Trace
Copepoda	3	2	Trace	Trace	Trace
Unidentified	1	1	Trace	1.7	0.1
Mollusca	303	144	23	279.5	22.2
Cephalopoda	4	4	1	115.4	9.2
Pelecypoda	76	42	7	64.4	5.1
Gastropoda	182	89	14	68.2	5.4
Amphineura	16	9	1	4.5	0.4
Scaphopoda	1	1	Trace	0.3	Trace
Unidentified	24	11	2	26.7	2.1
Echinodermata	338	120	19	165.7	13.2
Ophiuroidea	299	106	17	101.4	8.1
Echinoidea	18	14	2	31.0	2.5
Holothuroidea	2	2	Trace	27.5	2.2
Asteroidea	18	14	2	5.5	0.4
Unidentified	1	1	Trace	0.3	Trace
Annelida	809	164	26	72.9	5.8
Nereidiformia	284	85	13	27.3	2.2
Scoleciformia	25	9	1	1.6	0.1
Terebelliformia	47	12	2	10.8	0.8
Cryptocephala	110	2	Trace	0.1	Trace
Spioniformia	252	14	2	6.2	0.5
Sipunculida	--	--	--	--	--
Unidentified	91	70	11	26.9	2.2
Pisces	27	24	4	32.9	2.6
Miscellaneous	105	84	13	69.2	5.5
Urochorda	46	29	5	30.3	2.4
Coelenterata	3	3	Trace	7.6	0.6
Nemertea	10	4	1	0.2	Trace
Sand and stone	--	42	7	13.1	1.0
Animal flesh	5	5	1	4.5	0.4
Brachipoda	30	7	1	13.3	1.1
Turbellaria	--	--	--	--	--
Nematoda	10	4	1	0.2	Trace
Mucus	--	414	65	162.7	12.9
Unidentified	--	168	26	69.8	5.5

1/ Values less than 1.0 per cent are listed as trace.
2/ Values less than 0.1 per cent are listed as trace.

P. magellanicus, found in the haddock's diet were the soft body parts with the notable exception of the adductor muscle. There is heavy fishing for sea scallops in the Northeast Peak area. And on board ship the adductor muscle is removed and the remainder thrown overboard. Apparently it was the remains of scallops discarded by scallop fishermen that were eaten by the haddock.

Fish constituted 2.6 percent of the diet and were present in 4 percent of the specimens. This quantity of fish in the diet is slightly greater than the average for Georges Bank as a whole.

Southeast Part

A large area in the south central portion of Georges Bank has been designated the Southeast Part. Most of this area lies between the 30 and 50 fathom isobaths. Sand is the major substrate constituent with admixtures of shell fragments and gravel from place to place. The food habits of haddock in this portion of Georges Bank were determined by stomach analysis of 532 specimens from 19 collection stations. Mean body length of these specimens was 39 centimeters; extremes were 16 and 75 centimeters. Their average stomach content volume was 2.41 cubic centimeters.

Crustaceans were the major foods of haddock in this area. Mollusks and annelids were of secondary importance and echinoderms, fish, and miscellaneous groups were of minor value. The number, frequency, and volume of each group of stomach contents are recorded in table 7.

Amphipods and decapods were the primary crustacean forms preyed upon by haddock in this area. The amphipods provided 34.0 percent of the total stomach content volume and the decapods 5.3 percent. Considering all food groups, the amphipods ranked first in number and frequency of occurrence as well as in volume. One particular species of amphipod that occurred in enormous numbers was Byblis gaimardii (Kröyer). Other species frequently encountered were: Monoculodes edwardsi Holmes, Leptocheirus pinguis Stimpson, and Unciola irrorata Say.

Mollusks commonly eaten by haddock in this part of Georges Bank were: Colus pygamaeus Gould, Yoldia thraciaeformis Storer, Y. sapotilla Gould, and Solemy velum Say (and/or S. borealis). Very few living gastropods were eaten by haddock. In nearly all instances the gastropod shells were inhabited by hermit crabs. Invariably all shell-bearing mollusks found in haddock stomachs were of small size. Most specimens were less than 5 and 15 millimeters in height and length, respectively.

The sand dollar, Echinarachnius parma Lamark, was the predominant echinoderm in the food of haddock from this area. This species was most abundant in the samples from the western end of the Southeast Part. Again, only the small (3 - 20 millimeters in diameter) specimens were taken by haddock. Large specimens or pieces of large specimens were not observed in the stomach contents.

EVALUATION OF FOODS

Three criteria were employed for determining the importance of the various food items that were found in stomachs of haddock. They were as follows: (1) Percentage volume the volume calculated from the total stomach contents of all haddock representing the particular area or season under discussion, and expressed as a percentage. (2) Frequency of occurrence - determined by counting the number of stomachs in which the item occurred in the area or season. (3) Number of organisms - a summation of the number of specimens of each item found in the stomachs. In the calculation of averages and percentages

Table 7.--Stomach contents of 532 haddock from the Southeast Part of Georges Bank

Food groups	Number of organisms	Occurrence in stomach		Total volume	
		Number of stomachs	Percentage of stomachs[1]	Cubic centimeters	Percentage[2]
Crustacea	25,720	477	90	483.9	40.8
Amphipoda	24,380	470	88	403.5	34.0
Decapoda	659	124	23	62.5	5.3
Isopoda	190	79	15	12.5	1.0
Euphausiacea	--	--	--	--	--
Cirripedia	--	--	--	--	--
Mysidacea	--	--	--	--	--
Cumacea	474	147	28	5.4	0.5
Copepoda	13	9	2	--	--
Unidentified	4	3	1	--	--
Mollusca	305	134	25	210.0	17.7
Cephalopoda	1	1	Trace	103.0	8.7
Pelecypoda	262	110	21	71.2	6.0
Gastropoda	39	25	5	29.4	2.5
Amphineura	1	1	Trace	0.4	Trace
Scaphopoda	--	--	--	--	--
Unidentified	2	2	Trace	6.0	0.5
Echinodermata	442	112	21	55.0	4.6
Ophiuroidea	8	4	1	0.3	Trace
Echinoidea	428	105	20	53.7	4.5
Holothuroidea	--	--	--	--	--
Asteroidea	6	4	1	1.0	0.1
Unidentified	--	--	--	--	--
Annelida	715	187	35	176.4	14.9
Nereidiformia	284	76	14	71.7	6.0
Scoleciformia	306	54	10	56.7	4.8
Terebelliformia	11	7	1	3.0	0.3
Cryptocephala	8	3	1	0.8	0.1
Spioniformia	20	2	Trace	0.4	Trace
Sipunculida	--	--	--	--	--
Unidentified	86	27	5	43.8	3.7
Pisces	17	14	3	20.0	1.7
Miscellaneous	111	104	20	90.0	7.6
Urochorda	34	5	1	1.0	0.1
Coelenterata	24	14	3	34.2	2.9
Nemertea	40	18	3	27.5	2.3
Sand and stone	--	73	14	8.8	0.7
Animal flesh	3	3	1	11.5	1.0
Brachipoda	--	--	--	--	--
Turbellaria	8	4	1	7.0	0.6
Nematoda	--	--	--	--	--
Mucus	--	249	47	63.4	5.3
Unidentified	--	193	36	87.9	7.4

1/ Values less than 1.0 per cent are listed as trace.
2/ Values less than 0.1 per cent are listed as trace.

all stomachs were included. Some authors have omitted empty or nearly empty stomachs in their calculations.

The percentage volume method is undoubtedly the best single criterion for evaluating the relative importance of foods. It was the only method employed in this investigation which gave a measure of the bulk or mass of the various items. The frequency of occurrence and number of organisms yielded a useful indication of the availability and quantity of the organisms eaten. A well-rounded assessment of the comparative value of each food item can be gained by taking into consideration all three methods described above.

Certain species of animals were much more prevalent in the diet than others. No doubt the abundance and availability of particular organisms to the haddock were important factors contributing to the quantity eaten. Possibly the haddock's preference for particular items was another factor affecting the quantity taken. Evidence to resolve this question of species abundance has not been ascertained and must await further investigation. And, as explained previously in this report, there was considerable variation in dietary components from one location to another, but considering the entire area studied 11 species of animals were especially important in the diet. Judged according to the number, frequency of occurrence, and volume the following species were considered to be the most important foods of Georges Bank haddock:

Byblis gaimardii Kröyer	Amphipod
Monoculodes edwardsi Holmes	Amphipod
Unciola irrorata Say	Amphipod
Cancer irroratus Say	Rock Crab
Hyas coarctatus Leach	Toad Crab
Clymenella torquata (Leidy)	Annelid
Eunice pennata (O.F.Müller)	Annelid
Nereis pelagica Linnaeus	Annelid
Echinarachnius parma (Lamark)	Sand Dollar
Ophiopholis aculeata (Linnaeus)	Brittle-Star
Ophiura robusta Ayers	Brittle-Star

SEASONAL VARIATIONS

Haddock captured during the spawning period exhibited a pronounced decrease in stomach content volume. Because of the conflicting evidence on this subject it has been uncertain whether or not haddock abstain from feeding during the season for spawning. Information gathered by Welsh (Bigelow and Schroeder, 1953) in 1913 indicated that haddock are apt to fast during the spawning season. This contention was supported by Homans and Needler (1944). The opposite situation was found by Needler (1930). He reported spawning haddock of both sexes with well filled stomachs. Studies conducted by Vladykov and Homans (1935) and Ritchie (1937) found an intermediate situation to exist, in that only a decline in feeding took place during the spawning period rather than a complete cessation. This last view is corroborated by the data obtained in this investigation (table 8).

Distinct seasonal trends in diet composition were not evident although some rather wide variations occurred from month to month. An insight to seasonal trends in dietary components was gained by comparing the stomach content composition of specimens taken during six different months from the Northeast Peak, namely, during April, July, September, October, January, and February. Data from this analysis are presented in table 9.

Four of the more obvious monthly irregularities were the mollusks in the July samples, miscellaneous items in the January samples, and mucus in the January and February samples. The unusually large percentage of Mollusca in the July samples was due to several squid of large volume. A few pelagic tunicates (Salpa) in the January specimens resulted in the unusually high percentage for miscellaneous items. The quantity of mucus was found to be especially high in January and February samples. These months are the

Table 8.--Average volume of food[1/] per haddock by months

Month	Average volume of food (cubic centimeters)	Number of specimens	Average body length (centimeters)
January	3.0	44	54
*February	1.0	234	46
**April	1.6	256	35
*May	2.0	167	41
June	3.2	192	35
July	2.2	163	46
September	1.8	90	52
October	2.0	53	48
December	2.6	88	57

1/ Mucus, parasites, sand and stone not included in this tabulation.

* Spawning season.

Table 9.--Composition of stomach contents of haddock from the Northeast Peak, compiled by months and expressed as percentage volume

Item	April	July	September	October	January	February
Crustacea	53.6	24.5	35.4	34.9	16.8	26.8
Mollusca	3.3	34.7	10.5	15.0	7.5	27.9
Echinodermata	8.9	19.7	16.0	14.1	11.0	6.5
Annelida	13.2	4.4	7.9	8.5	5.8	1.4
Pisces	0.2	3.1	4.9	7.1	4.6	0.7
Miscellaneous	8.0	tr	11.5	6.4	39.3	5.4
Mucus	2.3	9.6	5.9	8.2	15.0	28.1
Unidentified	10.5	4.0	7.9	5.8	0	3.2
Number of stomachs	83	163	90	53	16	234
Total vol. (cc)	181.2	398.3	185.2	114.3	17.3	343.6
Av. vol/stom. (cc)	2.2	2.4	2.1	2.2	1.1	1.5
Av. body length (cm)	39	46	52	48	51	46

period during which haddock spawn, or immediately prior to it, when the fish slacken off in their feeding. The decrease in foods resulted in a disproportionately high percentage of mucus.

Differences in diet of specimens caught during the same month but from different locations within the food-type area were sufficiently large to overshadow any seasonal dietary changes that may have existed. From the data at hand, it appears that seasonal variations in diet composition of Georges Bank haddock are relatively minor in comparison to the variations associated with geographical distribution.

SIZE OF FOOD ORGANISMS

Haddock have a rather small, subterminal mouth and consequently are prevented from taking large articles of food. Most of the food organisms were small - between 1/2 and 3 centimeters in length - and the majority were narrow, elongate forms. Exceptions occurred, of course, but in general the food items with two dimensions greater than 1 or 2 centimeters in length were taken only by the very largest haddock.

Differences in the size of food organisms were, to some extent, correlated directly with the size of haddock. Small organisms such as amphipods, phyllodocid worms, cumaceans, and isopods were dominant in the food of small (14 - 30 centimeters) haddock. Large haddock (40 - 75 centimeters) contained the greatest share of fish, sipunculids, holothurians, asteroids, cephalopods, and other comparatively large items. The largest creature found in the haddock's diet was a squid, (Illex) whose body measured 20 centimeters in length and whose volume was 103 cubic centimeters. The predator of this squid measured 52 centimeters in body length. Food items as large as this are rarely encountered in the stomach contents of haddock. It is important to note, however, that small organisms were common in large haddock. In fact the predominant food in some collections of large haddock were organisms whose greatest lengths were less than 1 centimeter. This information suggests that the upper limit in size of food organisms is dependent upon the haddock's size, but through either preference or necessity small items constituted the bulk of the food of both large and small haddock.

Many species of groundfish with which haddock associate and with which they must compete for food, such as the cod, pollock, hake, skates, etc., have proportionately larger mouths. This puts the haddock at a disadvantage in competing for the larger food items, but the haddock, because their lips are muscular and somewhat prehensile, are better adapted than most of their associates for pulling worms and other soft-bodied creatures out of the ocean floor.

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SUMMARY

1. A quantitative analysis of the stomach contents of 1,287 haddock from Georges Bank, captured by means of otter trawls, form the basis of this study.

2. The average body length of all haddock examined was 44 centimeters. Minimum and maximum lengths were 14 and 75 centimeters, respectively. Calculated body weights averaged 2.1 pounds, with extremes from 0.1 to 9.2 pounds.

3. Stomach content volume varied from 0 to 110.0 cubic centimeters; average volume was 2.2 cubic centimeters.

4. Considering the entire area sampled, the primary food groups in decreasing order of importance were: crustaceans, mollusks, echinoderms, annelids, and fish.

5. Distinct differences in food of haddock from several parts of Georges Bank warranted the establishment of three food-type areas. These areas and the predominant food of haddock in each are as follows: Georges Basin - brittle-stars, Northeast Peak - decapod crustaceans, and Southeast Part - amphipods.

6. Most of the food organisms were small, sedentary or slow-moving benthic animals.

7. Differences in the food habits between large and small haddock were of a minor nature.

8. During the spawning season, February - May, the haddock contained smaller quantities of food than fish taken at other seasons of the year.

9. Seasonal trends in diet composition were not apparent.

10. In this study more than 173 species of food organisms were observed in the haddock's diet; only 11 species were present in large quantities.

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APPENDIX

A List of Organisms Found in Stomachs of Georges Bank Haddock

COELENTERATA
- Cerianthus borealis Verrill
- Epizoanthus americanus Verrill

PLATYHELMINTHES
- Planocerca Sp.

NEMERTEA
- Micrura sp.

ANNELIDA
- Ampharete arctica Malmgren
- Amphitrite sp.
- Aphrodita aculeata Linnaeus
- Arabella sp.
- Clymenella torquata (Leidy)
- Drilonereis filum (Claparede)
- Ephesia gracilis Rathke
- Eteone longa (Fabricius)
- Eualia sp.
- Eumida sanguinea Oersted
- Eunice pennata (O.F. Müller)
- Glyceria capitata Oersted
- Glyceria dibranchiata Enlers
- Goniada maculata Oersted
- Lumbrinereis acuta Verrill

ANNELIDA (cont'd.)
- Lumbrinereis fragilis (O.F. Müller)
- Marphysa sp.
- Nephthys incisa Malmgren
- Nereis pelagica Linnaeus
- Northria opalina Verrill
- Odontosyllis sp.
- Owenia fusiformis Delle Chiaje
- Pectinaria gouldii (Verrill)
- Phyllodoce mucosa Oersted
- Polydora sp.
- Rhodine loveni Malmgren
- Sabella crassicornis Sars
- Sabellaria vulgaris Verrill
- Samythella elongata Verrill
- Scalibregmia inflatum Rathke
- Stylaroides arenosa (Webster)
- Travisia carnea Verrill

- Phascolion strombi (Montagu)
- Phascolosoma gouldii Diesing

CRUSTACEA
- Balanus sp.

- Neomysis sp.

CRUSTACEA (cont'd.)

Diastylis sculpta G. O. Sars
Lamprops quadriplicata S.I. Smith
Leptocuma minor Calman

Aega sp.
Calathura branchiata (Stimpson)
Chiridotea tuftsi (Stimpson)
Cirolana polita Harger
Cirolana concharum (Stimpson)
Cyathura carinata (Kröyer)
Edotea montosa (Stimpson)
Janira sp.
Rocelina americana Schioedte & Meinert
Sphaeroma quadridentatum Say

Hyperia medusarum (Müller)
Themisto abyssorum (Boeck)
Parathemisto compressa (Göes) forma compressa
Parathomisto compressa (Göes) forma bispinosa
Amphithoe rubricata (Montagu)
Ampelisca spinipes Boeck
Anonyx mugax (Phipps)
Argissa hamatipes (Norman)
Byblis gaimardii (Kröyer)
Calliopius laeviusculus (Kröyer)
Corophium crassicorne Bruzelius
Corophium volutator (Pallas)
Ericthonius hunteri (Sp. Bate) ?
Erichthonius rubricornis (Stimpson)
Eusirus cuspidatus Kröyer
Gammarellus angulosus (Rathke)
Gammarus locusta (Linnaeus)
Gammaropsis melanops G. O. Sars
Haustorius arenarius (Slabber)
Hippomedon serratus Holmes
Ischyrocerus anguipes Kröyer
Lembos smithi (Holmes)
Leptocheirus pinguis (Stimpson)
Melita dentata (Kröyer)
Monoculodes edwardsi Holmes
Neopleustes pulchellus (Kröyer)
Orchomenella minuta (Kröyer)
Orchomenella Pinguis (Boeck)
Photis sp.
Photis macrocoxa Shoemaker

CRUSTACEA (cont'd.)

Phoxocephalus holbölli (Kröyer)
Podoceropsis nitida (Stimpson)
Pontharpinia spinosa (Holmes)
Pontogeneia inermis (Kröyer)
Protomedia fasciata Kröyer
Stenothoe cypris Holmes
Stenothoe minuta Holmes?
Stegocephalus inflatus Kröyer
Stenopleustes graciis (Holmes)
Sympleustes glaber (Boeck)
Tiron acanthurus Lilljeborg
Tmetonyx cicada (Fabricius)
Unciola irrorata Say
Unciola obliquua Shoemaker

Aeginina longicornis (Kröyer)
Caprella geometrica Say

Meganyctiphanes norvegica (M. Sars)

Axius serratus Stimpson
Cancer irroratus Say
Caridion gordoni (Bate)
Crago septemspinosus (Say)
Dichelopandalus leptocerus (Smith)
Hyas coarctatus Leach
Pagurus bernhardus (Linnaeus)
Pagurus kröyeri Stimpson
Pagurus pollicaris (Say)
Pandalus borealis Kröyer
Pandalus montagui Leach
Pontophilus norvegicus (M. Sars)
Eualus pusiola (Kröyer)

PYCNOGONIDA

Nymphon stromii Kroyer

MOLLUSCA

Ishnochiton sp.

Astarte undata Gould
Cardium sp.
Cerastoderma pinnulatum Conrad
Crenella decussata Montagu
Ouspidaria pellucida Stimpson
Ensis directus (Conrad)
Lyonsoa arenosa (Möller)

MOLLUSCA (cont'd.)

Macoma sp.
Nuculana tenuisulcata (Couthuoy)
Petricola pholadiformis Lamarck
Placopecten magellanicus Gmelin
Solemya velum Say
Venericardia borealis (Conrad)
Yoldia limulata (Say)
Yoldia sapotilla Gould
Yoldia thraciaeformis (Storer)

Dentalium entale Linnaeus

Amauropsis islandica (Gemlin)
Anachis haliaeeti Jeffreys
Colus pygmaeua (Gould)
Epitonium sp.
Lora sp.
Margarites groenlandicus (Gmelin)
Margarites sp.
Nassarius trivittatus Say
Natica sp.
Polinices sp.
Puncturella noachina Linnaeus
Pyramidella sp.
Retusa obtusa Montagu
Separatista cingulata Verrill
Trophon clathratus Linnaeus

Illex illecebrosus Lesueur

ECHINODERMATA

Asterias sp.
Crossaster papposus (Linnaeus)
Henricia sanguinolenta (O. F. Müller)
Hippasteria phrygiana (Parelius)
Leptychaster arcticus (M. Sars)
Poraniomorpha sp.

Amphiopholis squamata (Delle Chiaje)
Amphioplus sp.
Amphiura denticulata Koehler
Echinarachnius parma (Lamarck)
Ophiacantha bidentata (Retzius)
Ophiopholis aculeata (Linnaeus)
Ophiura robusta Ayres
Ophiura sarsi Lutken
Strongylocentrotus droehbachiensis (O.F. Müller)

Chirodota laevis (Fabricius)
Thyone scabra Verrill

BRACHIOPODA

Terebratulina septentrionalis Couthuoy

ASCIDIACEA

Molgula arenata Stimpson
Salpa zonaria (Pallas)
Salpa sp.

PISCES

Ammodytes americanus De Kay
Clupea harengus Linnaeus
Melanogrammus aeglefinus (Linnaeus)